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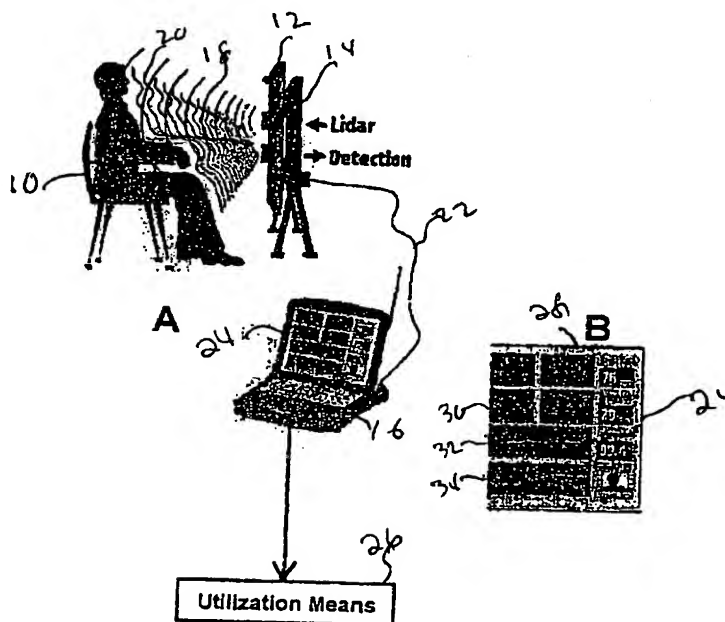
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(54) Title: **NON-INVASIVE POLYGRAPH TECHNOLOGY BASED ON OPTICAL ANALYSIS**



(57) Abstract: A system and method for unobtrusively and non-invasively subjecting a human subject to tests for the purpose of determining whether that subject is truthful and/or is under stress. A series of laser or infrared pulses are directed to the human subject. These pulses are reflected or scattered from the individual and are received by a receiver device. The receiver device is connected to an information processing device capable of determining various physiological characteristics exhibited by the human subject. A display associated with the information processing device would visually illustrate these physiological characteristics.

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NON-INVASIVE POLYGRAPH TECHNOLOGY  
BASED ON OPTICAL ANALYSIS

5

BACKGROUND OF THE INVENTION

1. Field of the Invention

10           This invention relates generally to polygraph systems and methods; and more particularly to such apparatus or procedures that require no mechanical contact with the subject.

2. Related Art

15           The art of the popularly designated "lie detector" is a mature one and well known. In it, ordinarily a subject to be interrogated is attached to various sensors for measurement of heart rate, breathing rate, perhaps skin characteristics and body temperature, and sometimes other body parameters. This  
20           technology is generally effective and a helpful tool, although the legal system has been traditionally somewhat slow to accept it because of recognized susceptibility to both false positive results (i.e., incorrect apparent finding of a lie when the subject has actually been truthful) and a false negative result  
25           (i.e., failure to detect an actual lie, or in other words, an incorrect finding of truthfulness).

            Polygraph testing and recording is either accompanied by, or part of, an interrogation of some kind, and in turn, commonly accompanied by audio and sometimes video recording.  
30           Thus, in order to conduct a full examination, operation of the recording polygraph devices themselves is additive with respect to, for instance, a video camera with a sound track.

            A drawback in conventional polygraphy is the need to attach the sensors before the examination and detach them  
35           afterward. Aside from the awkwardness of this procedure and the time consumed, some subjects are uncooperative or violent and may be dangerous to the operators of the equipment - while others may poses a hazard by virtue of highly communicable diseases such as  

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AIDS, hepatitis and ebola.

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Another difficulty with the conventional technology is the relatively high incidence of false positives due to a subject's nervousness about being connected to the apparatus and then questioned. A less-obtrusive system could significantly  
5 mitigate this problem.

Also, it is well known that some subjects are able to suppress bodily response to stress (leading to false negatives), and others can generate voluntary variations and correlations (leading to a continuing stream of false positives) that mask  
10 response to stress. In effect, the subject is lying not only to the questioner, but to the machine as well.

The problem of unwitting false positives also is complicated by the problem of intentional false positives. These various effects degrade the reliability of all conventional  
15 polygraphic systems and techniques.

Not all polygraphy is related to criminal testimony. Some is potentially useful instead in hiring applicants for sensitive jobs such as intelligence, police and other security work - or even simply positions calling for a high degree of  
20 personal stability and trustworthiness, as for instance, teachers, managers, pilots, bus drivers, medical and paramedical workers, and mass-transportation maintenance personnel.

In these areas, it is unseemly to subject applicants to the indignity or attaching leads and sensors to the skin. In  
25 common situations where only one polygrapher is available, an additional issue of sexual impropriety or at least offensiveness may arise when a subject and a polygrapher are of opposite gender.

Also, related to the characteristics of a polygrapher  
30 is the requirement for attention by a professional who is highly trained. A more highly automated system could reduce or eliminate the need for such advanced expertise - particularly if resulting primary data, without need for interpretation, could be used directly as evidence.

Results from conventional polygraphy do not appear to  
35 ~~be sufficiently consistent for such use. This field accordingly~~  
would benefit from refinement of the technology to provide more reproducible results from test to test.

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Finally, in most cases observation of a subject's body parameters is subject to considerations of civil liberties and personal privacy under the United States Constitution - and similar established policy worldwide; nevertheless, there are established circumstances under which such considerations are inapplicable or at least very severely attenuated. For example, it is understood that the law in much, if not all of the United States, accords to convicted felons while in prison a much lower degree of personal privacy than to citizens generally. Therefore it would be appropriate and desirable in such circumstances to have a means of monitoring vital signs without the subject's knowledge.

SUMMARY OF THE INVENTION

Accordingly, it would be desirable to provide a form of polygraphic equipment and methodology requiring no such sensor attachment, and also amenable to a wider range of vital parameters through a single sensor module.

A heretofore-unrelated art is that of light detection and ranging - sometimes called "lidar" by analogy to radio detection and ranging, and its better-known acronym "radar". More conspicuously, lidar has been used in large-scale aerial imaging, as in U.S. Patent 5,467,122 of Bowker et al directed to a streak-tube form of lidar for ocean-volume monitoring; but small- and even medical-scale applications are known as set forth in a related patent application of the same inventors, and to uses at a wide range of scales as disclosed in international application WO 97/18487 of Bowker et al.

The references just cited generally use a translating or scanning pulse source, with the receiver and transmitter substantially co-located. Through use of a streak-tube time resolver, they intrinsically map distance ("range"), between the transceiver and objects of interest, into position along one dimension (e.g., height) of a display screen - so that each pulse provides a sectional, two-dimensional image in a plane passing through the transceiver.

Due to the scanning or translation of the transceiver, successive pulses provide substantially parallel individual sectional images. These can then be integrated visually or otherwise into, effectively, a three-dimensional image.

Another well-known form of streak-tube lidar avoids the translation of the transceiver, substituting a different kind of remapping by use of a fiber-optic prism with rows of fiber-optic pixels physically rearranged - so that an entire two-dimensional image can be presented to a streak tube as a single line (i.e., one-dimensional) image. The streak tube is then able to time-resolve motion within the entire image, based on a single laser pulse; but a computer reassembly of the image - with its motion - is required since the image would otherwise appear unintelligibly scrambled by the original action of the fiber remapper.

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This technology is epitomized by well-known seminal patents of Knight and of Alfano. No fiber-optic remapper is needed in the scanning-transceiver systems; but the latter can acquire - with a single laser pulse - only a very small section of an entire three-dimensional image, whereas the remapping enables collection of an entire such image from each pulse.

In still another variant, sometimes called a "bistatic" configuration, the lidar transmitter and receiver are not co-located but rather, are in quite different locations. Here the laser pulses reflected from a subject are distorted by the effectively ellipsoidal character of the wavefronts reaching the receiver.

Here too, a computer reconstruction of the image is needed if the application at hand calls for a natural-appearing picture. Bistatic streak-tube lidar configurations are analogous to the similarly separated source/receiver configuration of radar systems.

A streak tube, however, is only one example of devices suited for time-resolution in lidar systems. Other alternatives will be introduced later in this document.

These several forms of lidar have been used to measure the conformation of land, or other objects, either directly in view or through turbid media that obscure direct vision. To the best of our knowledge, no connection has ever been suggested between lidar and polygraphy.

The three patent documents mentioned above, and all references cited therein, are wholly incorporated by reference into the present document. In particular, this incorporation shall include, but not be limited to, pictorial illustrations in those documents, which accordingly shall be regarded as directly presented in the present document.

As can now be seen, the related polygraphic art remains subject to significant problems, and the efforts outlined above - although praiseworthy - have left room for considerable refinement.

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BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a two-part conceptual illustration of a preferred embodiment of the invention;

FIGURE 2 is a transceiver diagram (subject to variant interpretations as explained below) representing more specifically the temporal/geometrical form of the pulses - and indicating spectral and temporal resolution of the return in the front end of a detector;

FIGURE 3 is a triplet of range waveforms at different pixels - the (A), (B) and (C) portions representing returns from portions of a subject's anatomical features that are successively more remote from the transceiver;

FIGURE 4 is a pair of information-flow diagrams showing at (A) data derivation from a single lidar pulse, and at (B) data derivation from automatic analyses and comparisons of plural pulses considered as a set;

FIGURE 5 is a comparative timing diagram showing plural graphs of vital-parameter excursion vs. time, as the basis of a simple time-series or coincidence analysis; and

FIGURE 6 is a graph of another data-evaluation approach that utilized correlation as the basis of analysis.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the invention provide a remote (i.e., noncontact) and if desired clandestine technique and apparatus for lie-detector tests, using analysis of three-dimensional lidar data. Such data are obtained by, for example, a range-gated electro-optical lidar camera system acquiring image-data frames at roughly 10 to 200 Hz (more preferably near the high end of this laser-pulse-rate range) over a relatively small area, in a generally continuous way with a pulsed laser source. Although this invention need not be so limited, the aforementioned relatively small area is an individual's face and its upper chest area.

Attention is directed to Figure 1A which shows the system of the present invention. This figure shows lidar pulse interaction with a subject 10. A lidar transmitter 12 transmits a pulsed beam 18 directed at the subject 10. A scattered pulse beam or reflected pulse beam 20 is obtained from the subject and is received by a lidar receiver 14. The lidar receiver 14 is generally co-located with respect to the lidar transmitter 12 in the form of a transceiver. However, it is noted that the lidar transmitter 12 and the lidar receiver 14 need not be required to be co-located. The lidar receiver 14 is connected to a computer 16 via a wire, cable or similar device 22, or by a wireless connection. The computer 16 contains a display 24 which is shown in more detail in Figure 1B. The computer 24 is provided with the requisite hardware and software to interpret the data received by the lidar receiver 14 to produce the various outputs shown in Figure 1B. The displays shown in Figure 1B can then be interpreted by a human operator as well as being transmitted to other utilization devices.

The display 24 illustrated in Figure 1B contains various outputs based upon various physiological parameters. These parameter include, but are not limited to, a subject's heartbeat, as shown by display 28, the subject's respiration rate, as shown by display 30 and the subject's body temperature, as shown by display 32. Display 34 illustrates an output created by automatically analyzing one or more of the aforementioned



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physiological parameters or other physical parameters. This output is produced by the appropriate software included in the computer 16 and is used to demonstrate visually whether the subject is under stress, as would be produced if the subject was not telling the truth.

Although not directly shown in Figure 1A, the computer 24 is also connected to, and controls, the lidar transmitter 12, allowing the transmitter 12 to be directed at various locations on the head and upper torso of the subject, as well as changing the frequency of the pulse based upon the type of parameter of interest. This control can be done manually, or would allow the lidar transmitter 12 to automatically scan the body of the subject as well as automatically change the frequency of the pulse.

The various parameters are analyzed based upon a change of distance from the transmitter and the subject's body as would be created from movement of the skin due to the subject's heart rate and respiration rate. Change in frequency of the received pulse from the transmitted pulse, as well as relative degree of scattering at the subject's skin surface would also be used to measure the various aforementioned parameters, as well as moisture on the subject's skin.

Figure 1A illustrates a system in which a low-power, short-pulse, is directed at a subject multiple times a second, detecting changes in heart rate, breathing rate, perspiration rate and subject temperature. An eye-safe infrared lidar could be used as well as other pulses, such as lasers. The computer 16 displays these measurements in near-real-time to aid an interrogation in determining stress and thereby in assessing the truthfulness of the subject.

Figure 1B suggests how the display is advantageously made to present all the key data, both graphically and numerically, and with a multiparameter-integrated figure of merit as shown by display 34, as well. In some applications, most particularly, outside a direct-interrogation context, any of the parameters (but particularly the parameter shown in display 34) may be used to operate other utilization devices 26. These utilization devices may incorporate any of a very great variety

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of devices. These may include, but are not limited to, access controls for doors, vehicles, computers, financial information or money (e.g., ATM machines) and so on.

As will be seen, however, the frame rate may depend very strongly on which of the above-outlined types of lidar system is in use. As mentioned earlier, a scanning system is simpler in terms of hardware, but also much slower in terms of overall three-dimensional frame rate.

This kind of apparatus is able to acquire a great range of vital signs - including, but not limited to, sweating (and, if so, the contents of the sweat), body temperature, heart rate, breathing rate, shivering or eye-blinking rate, and other parameters appropriate to monitoring of probable truthfulness in a subject.

In most-highly-preferred forms, the invention uses an active camera system, very finely range-gated with a very short-pulsed laser. The range-gate return is used to locate the surface of the subject's skin relative to the apparatus.

For this purpose, it is desirable to range-gate to millimeters. This objective calls for operation in the range of a few picoseconds to one nanosecond.

With skin position established, remaining variations of the signal provide the other parameters mentioned above. For instance, the relative degree of scattering at the surface, and particularly its variation over time, serves as an instantaneous indicator of moisture (i.e., sweat); and if desired, some limited amount of biochemistry in that moisture can be determined through analysis of spectral lines in the return.

Monitoring of minute periodic skin-range fluctuations, generally at frequencies of very approximately one per second (but between roughly 0.3 and 2.5 Hz) - and found at, for instance, the subject's temples - yield the heart rate. Like movements at the upper chest, throat, or nostrils, but slower (e.g., at frequencies in the range of 0.01 to 0.3 Hz) signify the respiratory rate; and at the eyes, the rate of blinking.

Small cyclical positional fluctuations in other areas,  
or even in the same areas (but characterized by substantially higher frequencies, e.g., 5 to 50 Hz), can reveal even a very

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slight trembling. In some of these operations, it is necessary to carefully discriminate beats (in the interfering-frequency sense) of the physiological activity against the pulse frequency of the laser.

5           Hence, a preferred embodiment of the apparatus filters the positional information into various frequency ranges, and separately monitors the amplitude and exact frequency of the data in each range. These signal channels can be read out on a display at the time of data acquisition - e.g., during an  
10           interrogation, which enables the equipment operator to dynamically control the course of questioning, as is the state of the art in conventional polygraphy - or can be saved for later, or preferably both.

15           Automatically derived correlations among the several parameters, and their time derivatives - i.e., acceleration, deceleration, or degree of abruptness in these changes - can also be characterized (i.e., "concern", "anxiety", "panic") and displayed or recorded. These, if preferred, can be treated as only advisory to the operator, whose professional interpretation  
20           is generally accorded greater reliability.

25           Preferred embodiments of the present invention, however, are capable of a reasonable degree of objectivity in output readings and their interpretation - much more so than in conventional polygraphy, as will be understood from the overall presentation in this document. This is partly due to the superior ability of the invention to deal with the problems of false positives and negatives.

30           While most of the equipment operates in an active mode (i.e., by analysis of radiation reflected by the subject from a pulsed laser), operation in the infrared enables collection of passive data as well - particularly including the subject's body temperature, found from its own very slight thermal radiation. An alternative (or confirming) measurement of temperature, however, can be found from very slight frequency changes in the  
35           laser return beam.

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By analyzing such changes, the apparatus can deduce the speed of sound at the subject's near interior surface, using phonon-photon interactions; temperature in turn is then deduced

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from the determined speed of sound. Such operation is based upon reported work, but as a practical matter, this operation is simple: the return signal is monitored at frequencies very slightly offset from the main, laser frequency. Certain spectral lines close-in to the laser line are due to a vibrational mode of water molecules, which reveals the desired sound speed and thereby the temperature value.

Relative to many of the established uses of lidar (particularly monitoring of small objects within turbid media), the present application intrinsically enjoys an unusually favorable signal-to-noise ratio. Preferred embodiments therefore can be operated to extract accurate and useful bioparameters from a relatively loosely operating system.

If desired, this apparatus can be placed in a housing that has the general appearance of an ordinary video camera, or for that matter, a potted plant or anything else. The same housing, in fact, can also accommodate a conventional video camera - or, as preferred, the lidar device itself can be configured and operated to acquire substantially conventional-appearing video images, as well as all the data discussed above.

To minimize subject awareness, the device can be operated in the infrared, with careful attention to eye-safety and sensitivity precautions. Satisfactory laser performance is now available at 1.04 to 1.07 microns, and for eye safety, the device is advantageously fitted with a conventional frequency doubler (e.g., from 1.07  $\mu\text{m}$  to 532 nm); the resulting light is then wavelength-tripled (the frequency is divided by three) to obtain eye-safe 1.5  $\mu\text{m}$  radiation. The invention also should be practiced with careful attention to invasion-of-privacy issues, generally as noted earlier.

The accompanying drawings show how preferred embodiments of the invention operate, and also illustrate several variants that are intended to emphasize the very great variety of alternative forms of both apparatus and method.

Figure 2 shall be understood to illustrate application of any one of several forms of lidar system in preferred embodiments of the present invention. These include the three

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previously discussed streak-tube lidar versions, and also certain alternatives that will be discussed below. The three streak-tube-based systems will be introduced first:

First, as understood to illustrate a scanning system, Figure 2 shows how it is possible to illuminate very shallow segments of the image - by a series of pulses a-g of the laser, directed in progressively shifted directions to scan over relevant parts of the subject's body - particularly where skin is exposed. This shifting of direction is preferably provided by a scanning mirror or set of mirrors, suitable angular rotation being obtainable by any of a great variety of means (such as a spinning polygonal mirror); or by a translating device closely analogous to the translating system disclosed in the art.

In such a system, each pulse generates a two-dimensional image as previously mentioned - that image plane passing through the transceiver position and being extended in one direction a-g of pulse propagation. As to the nearest image facet of the subject volume, each pulse generates essentially a single pixel row.

The successive pulses in the aggregate produce a three-dimensional image in which no remapping is needed - the interpretation of the image is far more natural, as seen in the cited work of Bowker et al - and the physical apparatus is somewhat simplified by absence of the fiber-optic remapper. To achieve adequately fast overall-frame rates (at least 10 Hz and preferably 200 Hz, as noted earlier) - for visualizing a subject's shivering, or blinking, or other relatively rapid bodily activity - the entire scanning operation must complete its cycle in a small fraction (1/200 to 1/10) of a second.

This leads to a high laser-pulse-rate requirement, for instance on the order of very roughly 10 kHz - which would enable a 160 Hz frame rate for a low-resolution 64-pixel-row frame. Such rates are possible, but somewhat drive up the cost of the apparatus; and a 64x64 frame is relatively unsatisfactory in terms of studying the subject's features and behavior visually.

At current-day technology, however, a medium-high-resolution system is not readily attainable in a pure scanning system. Laser pulse rates of about 80 kHz would be required for

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100 Hz frame rate and a medium-high-resolution 800-pixel-row frame; as will be seen, these frame and resolution objectives can be achieved, but using a preferred embodiment that is a variant system described below.

5 In a pure scanning system, the transmitter and receiver are most preferably co-located. For purposes of such a system, Figure 2 shows them separated only for convenience or practicality of illustration.

10 Second, as understood to illustrate a remapper system, Figure 2 shows how each laser pulse incorporates an array of pixel rows a-g. Here, unlike the interpretation just presented, the entire subject is illuminated in each laser pulse.

15 The entire returning two-dimensional subject image is then remapped into a single line, and that line preferably scanned in a streak tube to develop a three-dimensional image - which as mentioned earlier is scrambled. The remapping is readily unfolded, however, by simple computer operations.

20 A major advantage of this type of system is that the overall frame rate is the same as the laser pulse rate, rather than being slower by two to nearly three orders of magnitude. In a pure remapper system, as in the scanning system, the transmitter and receiver are co-located - and Figure 2 is to be understood as illustrating such co-location.

25 This arrangement does have drawbacks. Image resolution is limited by the preestablished number of pixels in the fiber-optic remapper, and arrays exceeding 64x64 pixels are progressively more costly or awkward - and the energy in the laser light is divided among the entire complement of pixels. Thus, although high frame rates are feasible, a medium-resolution  
30 image is not readily available in a pure-remapping system.

35 Third, as understood to illustrate a bistatic system, Figure 2 shows how the transmitter and receiver are not co-located, but rather, separated by some sizable angle. As mentioned earlier, this kind of geometry produces a relatively more complicated image; but once again, the image can be reconstructed by a computer. A bistatic system can be operated

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either with a scanning transmitter and scanning receiver, or with a remapper, as preferred.

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Hybrids of the scanning and remapping system are also possible and within the scope of the invention. As will now be understood, these different systems simply represent different ways of dividing up space and time for convenient and effective imaging.

Thus, for example, a remapper can be provided, but rather than remapping an entire image, the device can be formed to remap only some segment of intermediate shallowness. The laser pulse is angularly stepped or scanned, as in the case of the pure scanning system, but not as many steps are required.

Here computer reconstruction is required, but a smaller amount of data is handled per laser pulse. The number of pulses per full image frame, and the number of pixel rows in the remapper, are traded off against one another to optimize the overall system.

This hybrid system enables provision of an intermediate-resolution image at high pulse rates. For example, 800 pixel rows in 200 Hz frames would require 160 kHz laser pulses in a pure scanning systems - and would be mechanically impractical in a pure remapping system.

Such a frame-rate/resolution specification, however, is implemented straightforwardly with a hybrid. In one preferred embodiment, the remapper has 1100 pixel columns and two pixel rows (remapped to a single line of 2200 pixels total, which is just over half the pixel complement of a more-traditional 64x64 remapper), with the laser pulsing at only 200 to 400 Hz and the scan system stepping the beam by two pixels between pulses. This system has a very creditable near-photographic 1100x800-pixel image, and a frame rate in the range of 100 to 200 Hz.

As already mentioned, streak tubes are not the only suitable time-resolution systems for use with lidar imaging in the practice of the present invention. Other exemplary systems use instead, an array of small photomultiplier tubes (PMTs), or avalanche diodes, or a microchannel plate with a charge-coupled detector (CCD) array.

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These are all amenable to independent time-gating of individual pixels, which is desirable in preferred embodiments of the invention. Also, they are all effective at eye-safe wavelengths, which present-day streak tubes do not handle optimally.

In such an array, either the individual PMTs, diodes or CCD elements are tiny or an additional optical-coupling stage is used to spread the return laser beam, and essentially match it to the dimensions of the detector array. The array itself may be, merely by way of example, 64x64 elements.

The distance to the subject is ideally under about 10 m, and depending upon the several variants and the other parameters discussed above this may lead to pixel resolution on the subject of, for example, about 3 mm. Depth resolution should approach 0.3 mm. Although in principle data can be cached for later manipulation, this would preclude real-time preliminary assessment by an operator; therefore each pulse preferably is returned, sensed and analyzed before, or substantially at the same time as, the next pulse.

The scattered pulses are spectrally dispersed as by a diffraction grating, so as to enable the simple spectrometry mentioned earlier; and also range-gated. This means that the distance to impingement of each pulse on the nearest part (for that pulse) of the subject's body surface is used to start the time-resolution processes of the receiver. More-complicated gating is possible - as for example, setting the gate for each pixel by the previous image for that pixel, respectively.

One way in which such processes can provide extremely fine time resolution is by a streak-tube sweep such as discussed in the documents mentioned earlier. Those documents explain how the time interval of return of each pulse is essentially mapped to position along one dimension (e.g., height) of a streak-tube screen, as illustrated in the drawings of the patent documents and therein-cited art incorporated by references.

Such mapping causes that dimension on the screen to ~~represent distance from the lidar transceiver, or in other words~~ depth into the subject's body, as shown and explained at length



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in those earlier documents. As also mentioned in certain of the cited art, time resolution can be obtained through use of extremely fast electronics, without resort to a streak tube.

Meanwhile a transverse direction (perpendicular to the scan-sequence direction) is preserved as a spatial image direction, so that in the scanning-lidar form of the invention the streak-tube screen represents a tomographic visual section partway through the patient's body. As a patient's skin and flesh are not opaque, but rather turbid media, the analyses made by the automatic equipment extend slightly into the patient's body - to depths that are readily determined by simple systematic measurement.

Thus, the graph in Figure 3A represents pulse return from the air and the immediate interior of the patient's body, for a relatively near-in region of the anatomy - e.g., a hand held just in front of the body, or the subject's nose or chin projecting forwardly of other parts of the body. Those in Figure 3B and C represent similar air and immediate-interior returns, but from progressively more-remote regions of the anatomy such as the throat.

Merely by way of example, in a scanning system, these three returns might happen to be obtained in correspondence with the pulses a, b and c of Figure 2, and therefore could represent different bodily features sighted at different vertical positions; or instead might instead happen to be sighted at different horizontal position (pixels) along a common vertical position (pixel row).

In any event, the interior regions (flesh behind skin, bone behind hair, etc.) depicted in the drawing, are not merely distinguishable positionally, but also have respectively different characteristics. These different characteristics interact differently with a subject's stress.

Therefore, they offer opportunities to normalize the readings, or to partially calibrate the apparatus on-the-fly, etc. - for further refinement of the resulting polygraphic data. For instance, the laser-pulse reflectance of bone at a fixed, shallow depth within the body (e.g., at the forehead) is not likely to vary as a function of stress; therefore, in suitable

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subjects (i.e., where a clear bone return is found), the software can form ratios of the nearer-in, skin reflectance signals with the bone reflectance, thereby enabling stabilization of those net signal components which represent conditions at the skin.

5           Such stabilization or normalization is not strictly necessary, using a well-calibrated active system. It might, however, be employed in such a way as to enable a less-stable operation, or a less finely calibrated or adjusted apparatus, or a slower computational regime, or combinations of these  
10       relaxations of operating demands - and thereby to reduce the system cost or complexity.

          The invention is readily practiced by straightforward modification of an existing laboratory lidar system for scanning. Calibration for the various parameters of interest is also  
15       straightforwardly obtained from breadboarding of optically fast detectors to measure amplitude and frequency shift in the scattered signal from a representative subject.

          A journeyman programmer should have no difficulty preparing simple data-acquisition control software to record the  
20       measurements. Analysis software is more extensive but well within the state of the art; it should plot and assess in near-real-time:

- 25           •     Changes in amplitude, vs. time, of the reflected signal to determine changes in perspiration - such information being displayed after derivation from processing and comparison of individual pulses as detailed in Figure 4A, but the time-series (Figure 5) or correlation (Figure 6)  
30           analysis as well;
  - 35           •     Changes in carrier frequency - and subtended angle for the scattered signal, to establish small changes in body temperature - these variations too being developed from tracking of single pulses as in Figure 4A; and
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- Fast Fourier transform of ongoing multipulse measurements to extract breathing and heart rates (and preferably some other periodic parameters, of interest, as mentioned earlier) - as represented in Figure 4B.

As previously mentioned, and as illustrated here, the Figure 4 outputs are not limited to display, but are also readily thresholded and directed to drive utilization means. The mathematics of Fourier analysis, as well as the statistical methodologies of time series (Figure 5) or correlation (Figure 6), are now found commercially in software modules that can be plugged into the analysis software to be developed here.

Hence, these relatively sophisticated methods are available on an off-the-shelf basis for incorporation into practice of the present invention. As noted in Figure 6, a zero-correlation (or if preferred a resting-correlation) value can be automatically developed from the same subject and applied to set thresholds for the thresholding operations mentioned earlier.

In a preferred embodiment, temperature resolution and update rate are 0.1 °C and 0.1 Hz respectively. Heart-rate resolution and update rate are roughly one beat/minute and 0.1 Hz respectively.

Although the principles of the invention should now be clear, any newly assembled prototype apparatus should be carefully validated by controlled tests on a series of subjects, and overall operation subjected to a carefully crafted, statistically valid blind test demonstration. In this regard, it must be borne in mind that - given reliable bioparameter data, whether obtained from the present invention or conventionally - polygraphy itself is not an exact science.

As mentioned earlier, some subjects inadvertently generate false positives, while others can deliberately generate false negatives or positives (or both) at will, degrading the reliability of all direct polygraphic systems and techniques. ~~Conventional polygraphy provides little or no way to look behind the measurements, to determine whether observed reading patterns~~

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are arising in large part only from a subject's intentional, voluntarily screening of normal bodily responses - or are instead what they actually appear to be.

The present invention, however, does provide a way to look behind the superficial or apparent characteristics of the readings. It thereby offers several lie-detection advantages over conventional systems - particularly in that:

- (a) A subject's responses can be assessed when the subject does not know the invention is in use; and furthermore;
- (b) A subject's responses when the subject knows the invention is in use, can now be compared with responses when the subject does not know;
- (c) Such comparisons thereby enable detection of an open or truthful subject's fear of the apparatus itself, and also to quantification of such a subject's unintended disruption of the polygraphic process;
- (d) Such comparisons also enable detection of a guarded or deceptive subject's ability to intentionally, voluntarily generate false positives or negatives, and also to quantification of that ability; and finally
- (e) Such detection and quantification can lead in turn to some degree of cancellation of, or compensation for, the consequences of both (i) such unintended disruptions by a merely nervous subject, and (ii) such deceptive abilities on the part of a guarded subject.

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In these several distinct ways, the present invention can make very definite advances in the ability to deal with the problem of false positives and negatives in conventional

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polygraphy. Nevertheless, for a very conservative test, operation of the invention can be compared with that of conventional polygraphy as distinguished from any absolute measure of truthfulness in a wary or skillful subject.

5 By adapting and developing current IR lidar and detection technology, and standard fast Fourier transform algorithms, it is possible to measure changes in a subject's breathing, perspiration, heartbeat, blinking, shivering and temperature several times a second without physical contact - and  
10 if desired, without alerting the subject, whether during detention or during structured interviews. This capability must be tempered with due regard for applicable privacy rights and other applicable civil rights of the subject.

15 It will be understood that the foregoing disclosure is intended to be merely exemplary, and not to limit the scope of the invention.

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WHAT IS CLAIMED IS:

1. A system for non-invasively conducting polygraphic tests for determining the existence of stress on a human subject, comprising:

a transmitter provided at a distance from the human subject for producing a plurality of radiation pulses directed at the human subject;

a receiver provided at a distance from the human subject for receiving reflected or scattered radiation pulses from the body or face of the human subject, said reflected and said scattered radiation pulses containing information relating to a plurality of physiological characteristics indicative of stress or the truthfulness of the human subject; and

an information processing device in communication with said receiver for processing said reflected or said scattered radiation pulses.

2. The system in accordance with claim 1, further including a display device for displaying an output of said plurality of physiological characteristics.

3. The system in accordance with claim 2, wherein said plurality of physiological characteristics displayed by said display device includes at least one of the human subject's respiration rate, heart rate and temperature.

4. The system in accordance with claim 2, wherein said plurality of physiological characteristics includes the human subject's perspiration and said information processing device includes a spectral analyzation device for determining the existence of perspiration on the human subject's body.

5. The system in accordance with claim 2, wherein said information processing device utilizes said plurality of ~~physiological characteristics to produce a single output~~ displayed on said display device indicative of the truthfulness of the human subject.

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6. The system in accordance with claim 3, wherein said information processing device utilizes said plurality of physiological characteristics to produce a single output displayed on said display device indicative of the truthfulness of the human subject.

7. The system in accordance with claim 4, wherein said information processing device measures changes in amplitude versus time of said reflected signal to measure perspiration of the human subject.

8. The system in accordance with claim 3, wherein said information processing device measures changes in the carrier frequency of said scattered radiation pulses to measure the temperature of the human subject.

9. The system in accordance with claim 3, wherein said receiver is provided with a time gating device to determine the distance between said receiver and the human subject.

10. The system in accordance with claim 9, wherein said information processing device utilizes a fast Fourier transform of a series of reflected radiation pulses to measure the respiration rate and the heart rate of the human subject.

11. The system in accordance with claim 1, wherein said transmitter produces a plurality of radiation pulses which are progressively shifted over at least a portion of the human subject's body.

12. The system in accordance with claim 1, wherein said transmitter produces a plurality of radiation pulses, all of which are directed at the same portion of the human subject's body, and said information processing device includes a remapper.

13. The system in accordance with claim 1, wherein said transmitter produces a plurality of laser pulses.

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14. The system in accordance with claim 1, wherein said transmitter produces a plurality of infrared pulses.

15. The system in accordance with claim 1, wherein said transmitter and said receiver are co-located.

16. A method for non-invasively conducting polygraphic tests or determining the existence of stress on a human subject, comprising the steps of:

producing a series of radiation pulses from a transmitter;

directing said series of radiation pulses toward a human subject provided at a distance from said transmitter;

receiving reflected or scattered radiation pulses from the human subject by a receiver provided at a distance from the human subject; and

analyzing said reflected or said scattered radiation pulses to determine various physiological characteristics of the human subject which are indicative of the stress of the human subject and the truthfulness of the human subject.

17. The method of claim 16, including the step of establishing the distance between the human subject and said transmitter and said receiver.

18. The method of claim 17, including the step of establishing said transmitter and said receiver at the same location.

19. The method in accordance with claim 17, including the step of interrogating the human subject with questions during said producing and said directing steps.

20. The method in accordance with claim 16, further including the step of visually displaying each of said various physiological characteristics developed by said analyzing step.

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21. The method in accordance with claim 19, further including the step of visually displaying each of said various physiological characteristics developed by said analyzing step.

22. The method in accordance with claim 20, further including the steps of:

calculating a single output of said various physiological characteristics of the human subject which is indicative of the truthfulness of the human subject; and  
visually displaying said single output.

23. The method in accordance with claim 21, further including the steps of:

calculating a single output of said various physiological characteristics of the human subject which is indicative of the truthfulness of the human subject; and  
visually displaying said single output.

24. The method in accordance with claim 16, wherein said analyzing step measures changes in amplitude versus time of said reflected radiation pulses which is a measure of the perspiration of the human subject.

25. The method in accordance with claim 16, wherein said analyzing step measures changes in the carrier frequency of said scattered radiation pulses which is a measure of the temperature of the human subject.

26. The method in accordance with claim 17, wherein said analyzing step utilizes a fast Fourier transform to measure the heart rate and the respiration rate of the human subject.

27. The method in accordance with claim 16, wherein said series of radiation pulses produced by said transmitter are progressively shifted over at least a portion of the human subject's body.

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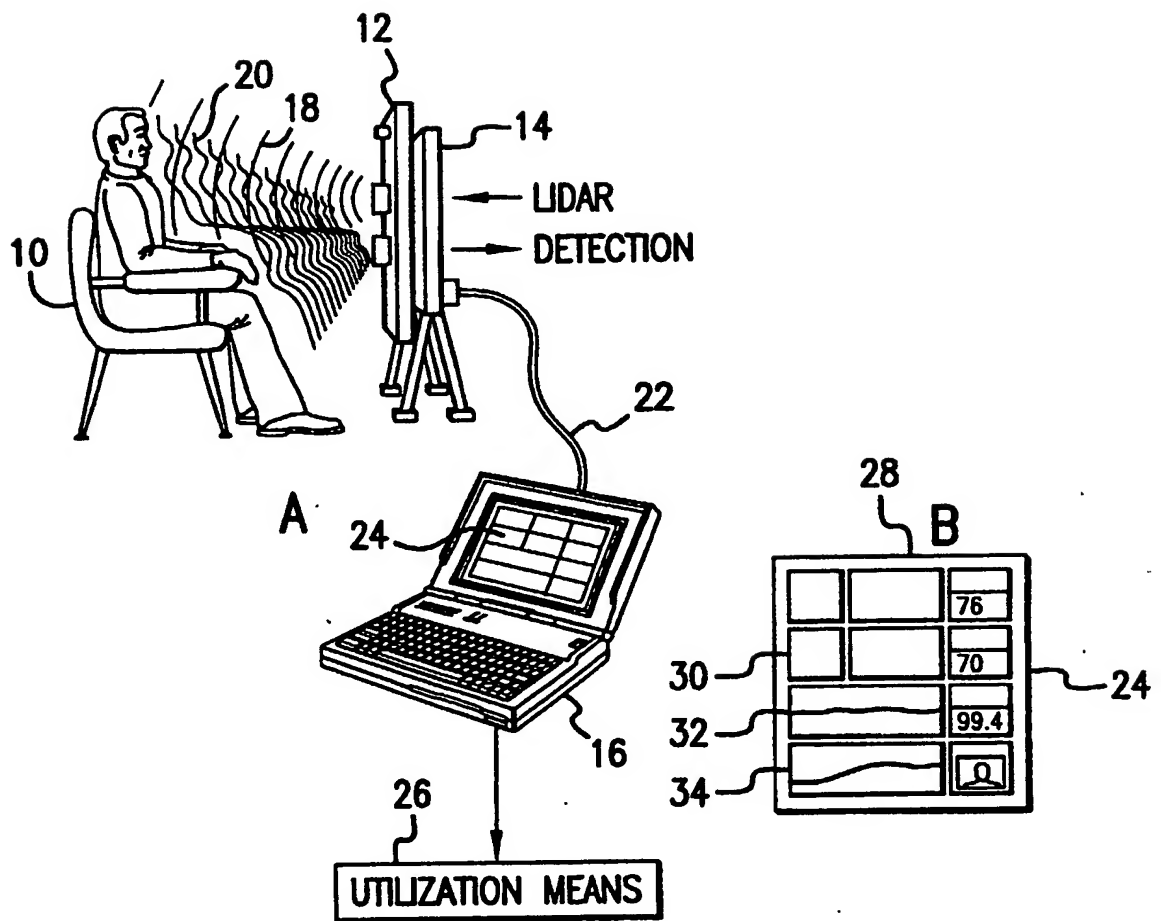
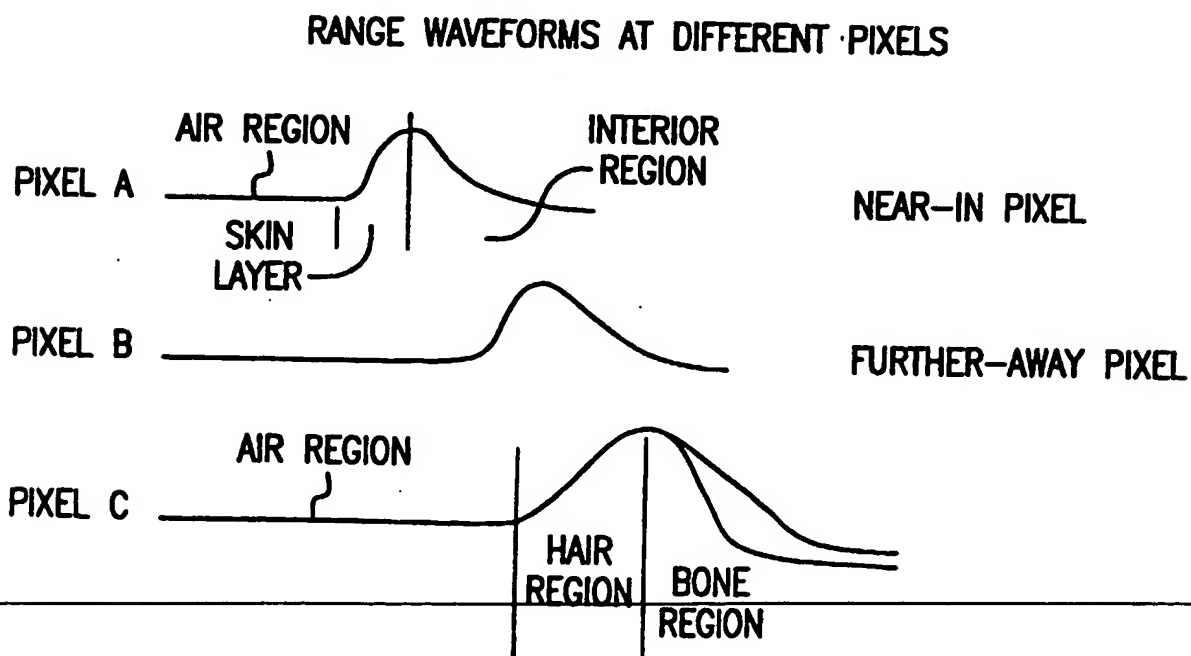
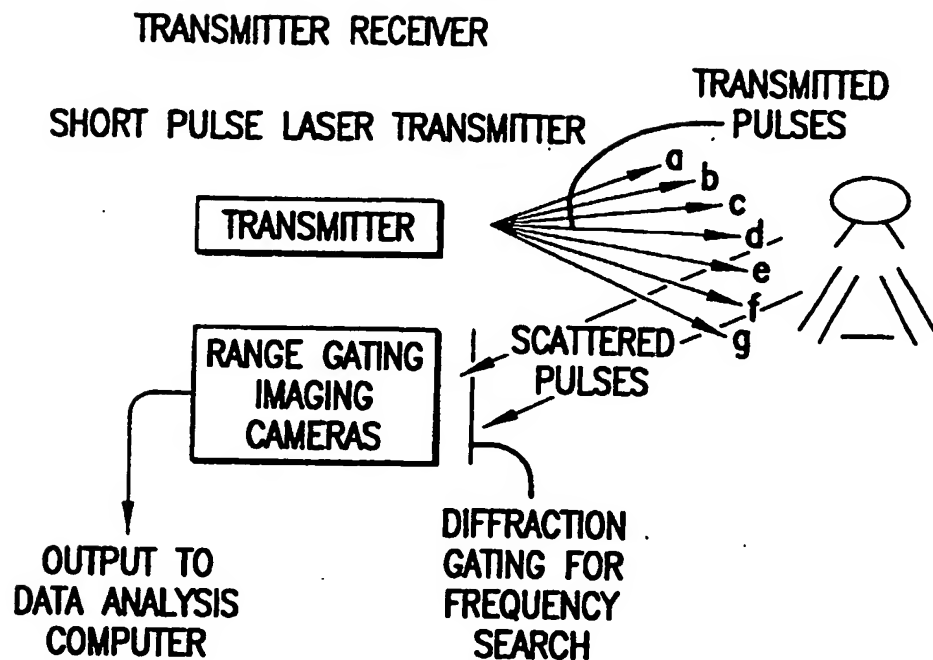


FIG. 1

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SUBSTITUTE SHEET (RULE 26)

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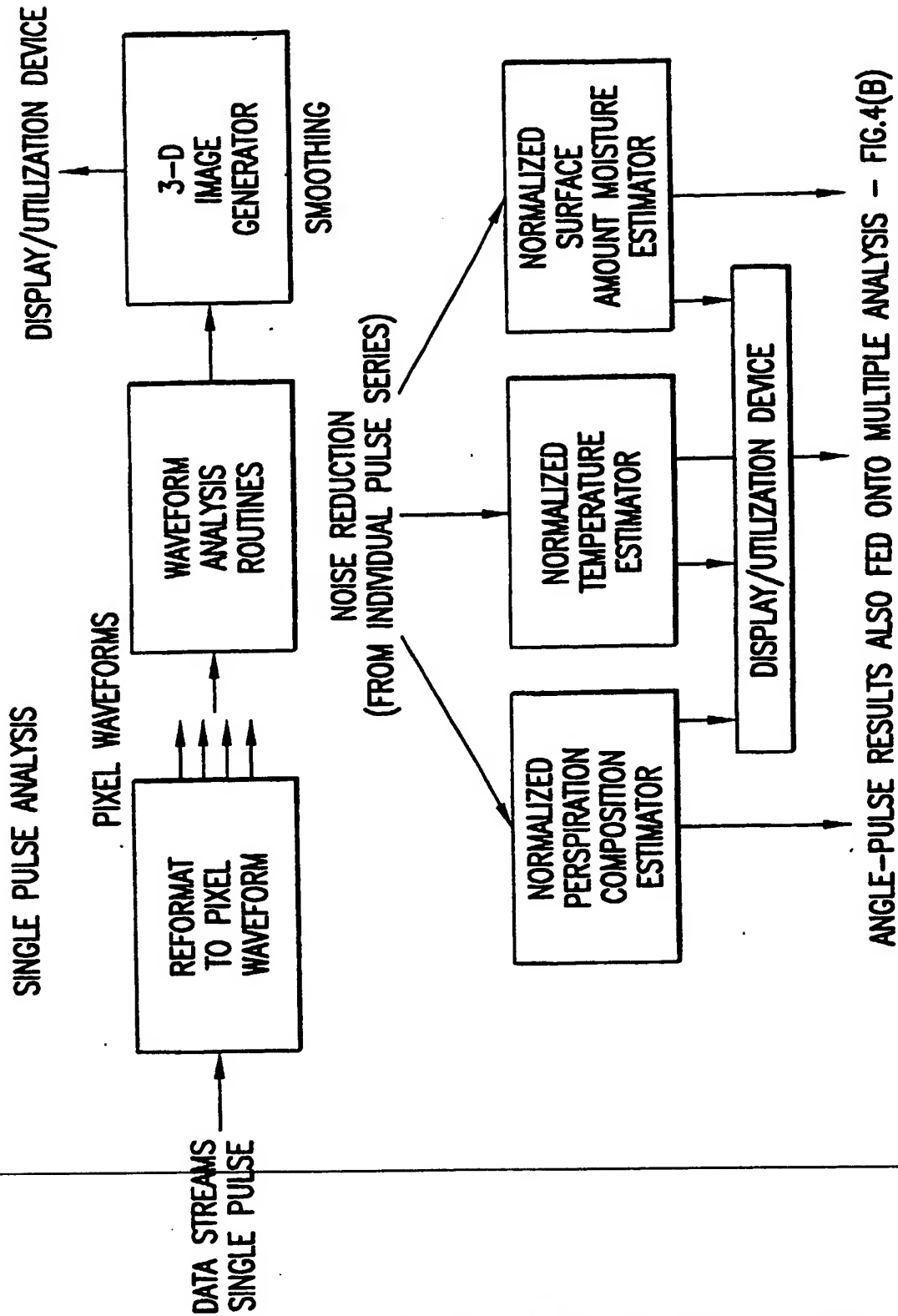


FIG.4A

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## MULTIPLE PULSE ANALYSIS

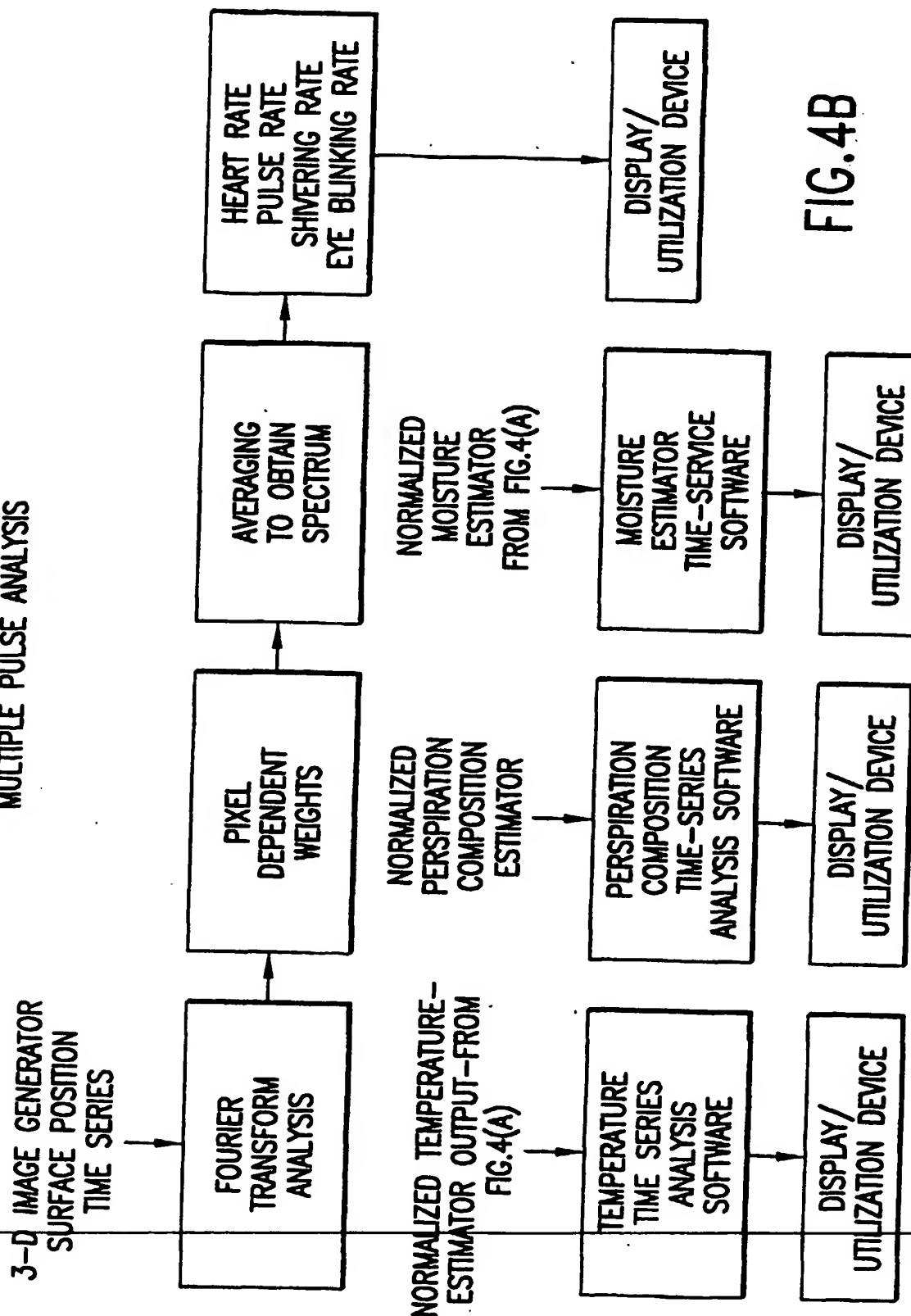


FIG.4B

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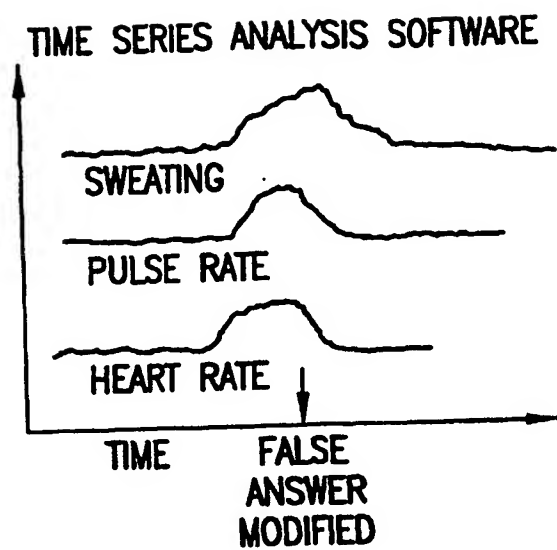


FIG.5

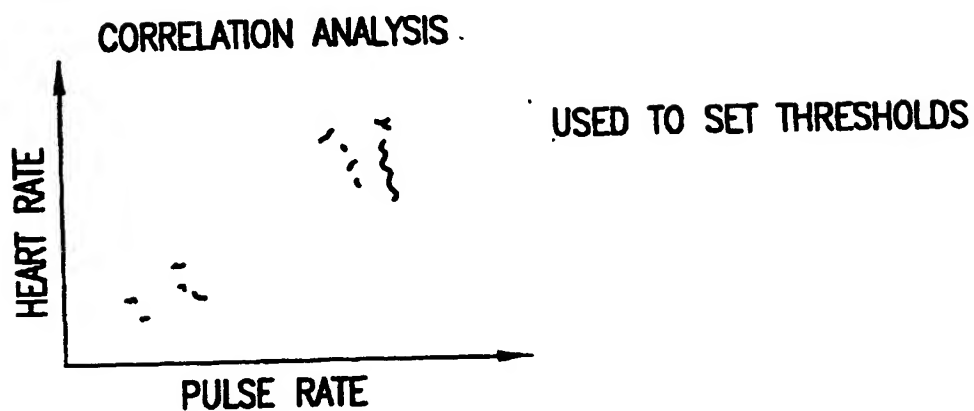


FIG.6

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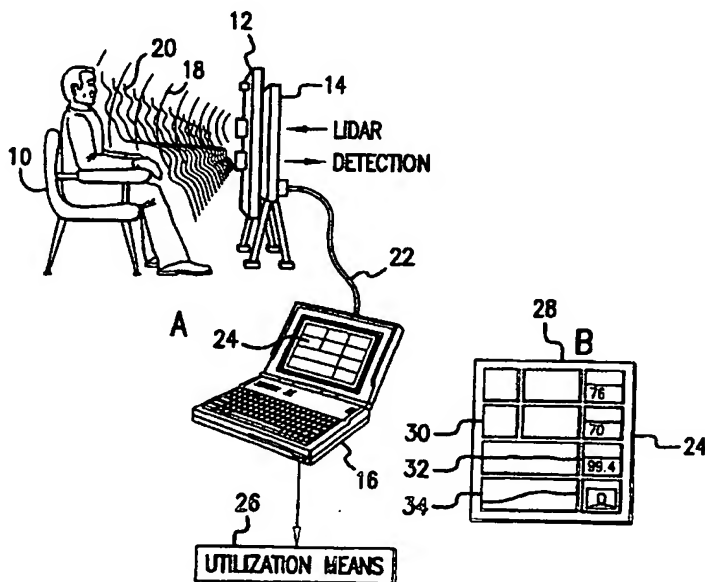
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(72) Inventor: **LUBARD, Stephen, C.**; 4812 Don Juan Place,  
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(54) Title: **NON-INVASIVE POLYGRAPH TECHNOLOGY BASED ON OPTICAL ANALYSIS**



(57) Abstract: A system and method for unobtrusively and non-invasively subjecting a human subject (10) to tests for the purpose of determining whether that subject is truthful and/or is under stress. A series of laser or infrared pulses (18) are directed to the human subject (10). These pulses are reflected or scattered (20) from the individual and are received by a receiver device (14). The receiver device (14) is connected to an information processing device (16) capable of determining various physiological characteristics exhibited by the human subject (10). A display (24) associated with the information processing device (16) would visually illustrate these physiological characteristics.

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# INTERNATIONAL SEARCH REPORT

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## A. CLASSIFICATION OF SUBJECT MATTER

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US CL : 600/300

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 600/300, 301, 306, 310, 407, 473, 587

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2,944,542 A (Barnett et al.) 12 July 1960 (12.07.1960), entire document.	1 - 27
Y	US 3,230,951 A (Teschner) 25 January 1966 (25.01.1966), column 3, lines 5 - 19.	2, 20, 21
X	US 4,085,740 A (Allen, Jr.) 25 April 1978 (24.04.1978), column 1, lines 4 - column 5, line 9.	1, 11, 12, 15 - 19, 27
Y		2 - 5, 7 - 9, 20, 21, 24, 25
A	US 4,289,142 A (Kearns) 15 September 1981 (15.09.1981), entire document.	1 - 27
Y	US 5,792,049 A (Eppstein et al.) 11 August 1998 (11.08.1998), column 8, line 3 - column 16, line 46.	4, 7, 24
Y	US 5,892,575 A (Marino) 06 April 1999 (06.04.1999), column 1, line 23 - column 18, line 20.	2, 3, 5, 8, 9, 20, 21, 25

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

\* Special categories of cited documents:

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document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

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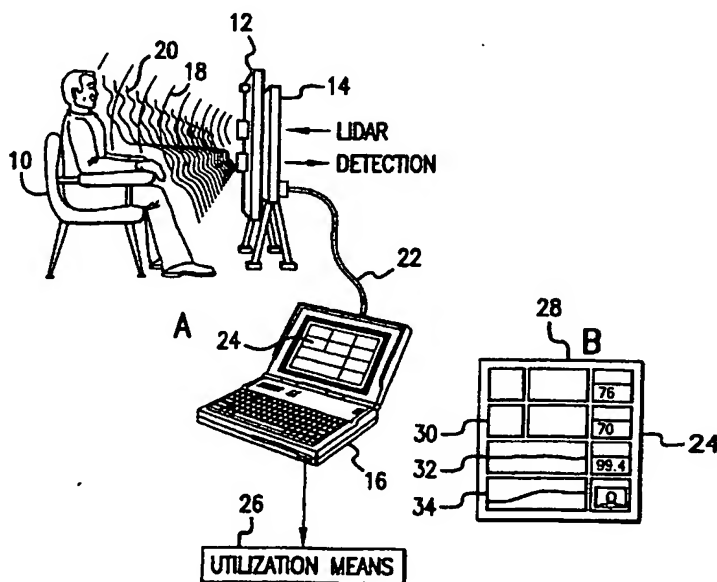
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- (71) Applicant: DEFENSE GROUP INC. [US/US]; 2034 Eisenhower Avenue, Suite 115, Alexandria, VA 22314 (US).
- (72) Inventor: LUBARD, Stephen, C.; 4812 Don Juan Place, Woodland Hills, CA 91364 (US).
- (74) Agents: WASSON, Mitchell, B. et al.; Hoffman, Wasson & Gitler, P.C., Suite 522, 2361 Jefferson Davis Highway, Arlington, VA 22202 (US).
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
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(54) Title: NON-INVASIVE POLYGRAPH TECHNOLOGY BASED ON OPTICAL ANALYSIS



(57) Abstract: A system and method for unobtrusively and non-invasively subjecting a human subject (10) to tests for the purpose of determining whether that subject is truthful and/or is under stress. A series of laser or infrared pulses (18) are directed to the human subject (10). These pulses are reflected or scattered (20) from the individual and are received by a receiver device (14). The receiver device (14) is connected to an information processing device (16) capable of determining various physiological characteristics exhibited by the human subject (10). A display (24) associated with the information processing device (16) would visually illustrate these physiological characteristics.



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**AMENDED CLAIMS**

**[Received by the International Bureau on 22 SEP 2003 (22.09.03) ;  
original claims 1 and 16, amended]**

1. A system for non-invasively conducting polygraphic tests for determining the existence of stress on a human subject, comprising:

a transmitter provided at a distance from the human subject for producing a plurality of coherent radiation pulses directed at the human subject;

a receiver provided at a distance from the human subject for receiving reflected or scattered radiation pulses from the body or face of the human subject, said reflected radiation pulses including a measurable frequency shift between said coherent radiation pulses and said reflected radiation pulses, said measurable frequency shift and said scattered radiation pulses containing information relating to a plurality of physiological characteristic indicative of stress or the truthfulness of the human subject; and

an information processing device in communication with said receiver for processing said measurable frequency shifts and said scattered radiation pulses.

2. The system in accordance with claim 1, further including a display device for displaying an output of said plurality of physiological characteristics.

3. The system in accordance with claim 2, wherein said plurality of physiological characteristics displayed by said display device includes at least one of the human subject's respiration rate, heart rate and temperature.

4. The system in accordance with claim 2, wherein said plurality of physiological characteristics includes the human subject's perspiration and said information processing device includes a spectral analyzation device for determining the existence of perspiration on the human subject's body.

5. The system in accordance with claim 2, wherein said ~~information processing device utilizes said plurality of~~ physiological characteristics to produce a single output displayed on said display device indicative of the truthfulness of the human subject.

14. The system in accordance with claim 1, wherein said transmitter produces a plurality of infrared pulses.

15. The system in accordance with claim 1, wherein said transmitter and said receiver are co-located.

16. A method for non-invasively conducting polygraphic tests for determining the existence of stress on a human subject, comprising the steps of:

producing a series of coherent radiation pulses from a transmitter;

directing said series of coherent radiation pulses toward a human subject provided at a distance from said transmitter;

receiving reflected or scattered radiation pulses from the human subject by a receiver provided at a distance from the human subject, said reflected radiation pulses including a measurable frequency shift between said coherent radiation pulses and said reflected radiation pulses; and

analyzing said measurable frequency shift and scattered radiation pulses to determine various physiological characteristics of the human subject which are indicative of the stress of the human subject and the truthfulness of the human subject.

17. The method of claim 16, including the step of establishing the distance between the human subject and said transmitter and said receiver.

18. The method of claim 17, including the step of establishing said transmitter and said receiver at the same location.

19. The method in accordance with claim 17, including the step of interrogating the human subject with questions during said producing and said directing steps.

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~~20. The method in accordance with claim 16, further~~  
including the step of visually displaying each of said various physiological characteristics developed by said analyzing step.

### AMENDED SHEET (ARTICLE 19)